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Prompt photon A_N with the PHENIX MPC-EX detector

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Abstract

The PHENIX MPC-EX detector is a Si-W preshower extension to the existing Muon Piston Calorimeters (MPC). The combined detectors will make possible a measurement of the prompt photon single spin asymmetry A_N in 200GeV transversely polarized p+p collisions, which will help elucidate the correlation of the transverse motion of valence partons in the proton with the proton spin.

1 Introduction

The large transverse single-spin asymmetries observed in polarized p+p collisions at RHIC [1, 2] are believed to be related to a combination of initial and finall state effects that originate primarily in the valence region of the projectile nucleon. While data in semi-inclusive deep-inelastic scattering has been used to constrain these effects [3], the situation is more complicated in p+p collisions due to the presence of both strong initial and final-state corrections arising from the soft exchange of gluons.

Existing measurements at forward rapidity in transversely polarized p+p collisions are limited to hadronic observables, and therefore sample a number of different partonic processes. In contrast, direct photon production at forward rapidity is dominated by the scattering of a valence quark from the polarized projectile off a low-x gluon in the unpolarzied proton. Theoretical studies indicate that the contribution from transversity and a polarized fragmentation function is small [4], so that the single spin asymmetry for fragmentation photons largely carries the same information about the initial state of the polarized nucleon and reinforces the asymmetry from direct photons. Fragmentation photons can be difficult to disentangle from direct photons, so they are commonly combined and referred to as "prompt" photons.

The prompt photon signal must be extracted from a large background of photons from hadronic decays, primarily from π^0 and η mesons. The MPC-EX is a Si-W preshower detector that will be installed in front of the existing PHENIX MPCs. The MPC's are lead-tungstate electromagntic calorimeters

covering rapidities $3.1 < |\eta| < 3.8$. The new detector will consist of eight layers of Si minipad sensors interleaved with W absorber and enable the identification and reconstruction of π^0 mesons at energies up to > 80 GeV. The capability of the MPC-EX to reconstruct and reject π^0 mesons (as well as other hadronic sources of photons) at very high energies is essential to separate prompt photons from other sources of photons.

2 The MPC-EX Preshower Detector

The MPC-EX will be located approximately two meters from the interaction vertex, inside the muon magnet pistons. The MPC-EX itself will consist of eight measurement layers, each layer separated by a 2 mm thick W absorber. The active area of each layer will consist of $500\mu m$ thick Si "minipad" 6.2 x 6.2 cm^2 sensors. The sensor itself is divided into 1.8 mm by 15mm minipads to provide 128 separate channels per sensor. The orientation of the sensors will alternate by 90^o in successive layers. The readout electronics will consist of two SVX4.2b ASICs per module, and a capacitive split will provide both a high gain and low gain channel for each minipad, for a total or 256 channels per module. The modules will be installed on an electronics carrier board that will provide readout and bias voltage for the individual sensors. The carrier board itself will be bonded to the W absorber for each layer.

Clusters from high momentum π^0 decays ($E > 20$ GeV) merge in the MPC and are indistinguishable from a single high energy photon. With the MPC-EX in place, the resolution of the individual minipad elements generates a highly detailed picture of the early development of the electromagnetic shower of each photon. Distinct centers of gravity can be identified for each photon shower and a four vector reconstructed from the MPC-EX shower and energy, and the total energy deposited in the MPC. These four vectors can be combined to reconstruct an invariant mass for the combined shower. This technique will allow the measurement of the π^0 and η meson production nearly out to the kinematic limit in 200 GeV p+p collisions.

3 Prompt Photon A_N

Extensive simulations have been undertaken to demonstrate the ability to extract a prompt photon signal using the MPC-EX. Approximately 870M PYTHIA events were generated that included all minimum bias processes as well as the production of direct and fragmentation photons. The event sample

was put through a full simulation of the PHENIX detector, including the MPC-EX. The data was digitized with the response of the detectors and then reconstructed. A set of basic cuts to remove background direct photons from π^0 and charged hadron interactions were applied. Because the ratio of prompt photons to photons from π^0 decays improves as a function of transverse momentum we examined all candidates with a transverse momentum $p_T >$ 3GeV/c. With these cuts the reconstruction efficiency for prompt photons was 31%, while the reconstruction efficiency for photons from π^0 mesons was only 2.9%, indicating an improvement in the prompt photon/π^0 ratio of more than a factor of ten.

In a direct photon measurement with the MPC-EX detector, the signal of prompt photons (S) and the background of hadron-decay photons (B) are mixed. Simulations show $S/B \approx 0.4-0.5$ at $p_T > 3$ GeV/c. In measurements of a prompt photon A_N in 200 GeV p+p collisions, the background photon events will carry a non-zero asymmetry, such as from π^0 or η decay photons. The background asymmetry can be subtracted based on measurements of the π^0 and η asymmetries.

Assuming a sampled luminosity of 50 pb^{-1} and a cut of $p_T > 3$ GeV/c, 0.75 million photon events will be observed in the MPC-EX. The simulated events are split into bins that corresponding to central values of (p_T, x_F, number of events) as: (3.2, 0.47, 400k), (3.6, 0.54, 250k), (4.0, 0.61, 75k) and (4.4, 0.75, 25k). We assume that MPC-EX can independently measure the asymmetry of mesons the π^0 and η mesons to a precision at least a factor of two better than the inclusive photon asymmetry in each bin. The estimated precision of the prompt photon A_N is shown in Figure 1.

4 Conclusion

The MPC-EX is a novel Si-W preshower detector that will enable the measurement of prompt photons as forward rapidities in transversely polarized p+p collsions at $\sqrt{s} = 200$GeV. The detector is currently under construction, and a test run with partial instrumentation is planned for fall 2013, (RHIC Run-14) with complete installtion in both PHENIX arms for fall 2014 (RHIC Run-15). Measurement of the prompt photon single spin asymmetry in transversely polarized p+p collisions will help elucidate the origin of single spin asymmetries in hadronic collisions.

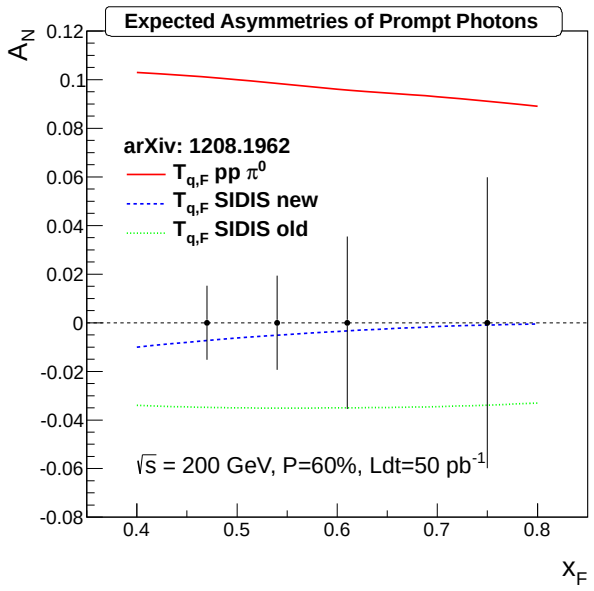

Figure 1: Projected sensitivity for the prompt photon single spin asymmetry with the MPC-EX assuming an integrated luminsoity of 50 pb^{-1} and 60% beam polarization. The sensitivities are shown compared to calculations in the collinear factorized approach [4, 5] using a direct extraction of the quark-gluon correlation function from polarized p+p data (upper solid curve), compared to the correlation function derived from SIDIS extractions (lower dotted and dashed curves).

References

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